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gives a corresponding value of 100 volts per centimeter. It therefore seems safe to say that the electric field-strength at the level in question is less than 200 volts per centimeter.[4]

Salet and Millochau, using lower dispersion, had previously found a maximum value of 7000 volts per centimeter for $H\gamma$ in the chromosphere.[5] Our much lower value indicates that in order of magnitude the electrical potential differences in the solar atmosphere may not greatly exceed those in the lower atmosphere of the earth, where they average about 1 volt per centimeter. In thunderstorms, of course, enormously greater differences occur, and it remains to be seen whether appreciable electric fields can be detected in solar eruptions, where the conditions for their production appear to be more favorable than in the quiet regions of the atmosphere.

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[1] For a summary of the views of Goldstein, Bigelow, Deslandres, Arrhenius, and others on the electrical condition of the solar atmosphere see Bosler, *Les théories modern du soleil;* also recent papers in the *Comptes Rendus Paris Acad. Sci.*

[2] See Stark, *Elektrische Spectralanalyse chemischer Atome*, Hirzel, Leipzig, 1914.

[3] Hale, Solar Magnetic Phenomena, *Proc. Amer. Phil. Soc.*, April 24, 1914, p. 254.

[4] Under high dispersion, Stark has resolved $H\delta$ into many components (loc. cit., Plate III). A variation in the relative intensities of these components under solar conditions, which is not improbable, might introduce an error into a determination of the maximum intensity of the electric field. It is likely, however, that the results here given are of the true order of magnitude.

[5] Salet and Millochau, *C. R. Paris Acad. Sci.*, **158**, 1000 (1914).

RESULTS OF AN INVESTIGATION OF THE FLASH SPECTRUM WITHOUT AN ECLIPSE

REGION λ 4800 TO λ 6600

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The study of the bright line spectrum given by the comparatively thin layer of gases which constitutes the sun's atmosphere has usually been limited to the brief periods of total solar eclipses. During the few minutes that the dark body of the moon covers the sun's image the spectrum of the shell of radiating gases surrounding the sun may be observed without difficulty, and photographs of this spectrum, known to astronomers as the spectrum of the flash, have formed one of the most important products of recent eclipse expeditions.

Although admirable results have been secured in this way the short duration of eclipses has necessitated the use of spectroscopes of moderate power, and as a consequence the determination of the bright line wave-lengths has by no means reached a degree of accuracy comparable with that of the dark lines of the solar spectrum. Accordingly such questions as relate to small differences of wave-length between solar and flash spectrum lines, as well as some which depend upon the structure of the lines have of necessity remained unsettled.

It was shown by Young, Lockyer and others that the flash spectrum might be observed without an eclipse under conditions of good definition and high transparency, and Young was enabled to observe a considerable number of bright lines visually. Through the use of photographic methods this work was extended greatly by Hale at the Kenwood Observatory and later at the Yerkes Observatory with the 40-inch refracting telescope. With this instrument he observed visually the green carbon fluting in the flash spectrum which lies in a very thin stratum close to the sun's visible edge.

The photography of the flash spectrum was one of the investigations undertaken with the 60-foot tower telescope of the Mount Wilson Observatory and the 30-foot spectrograph used in conjunction with it. A preliminary account of some of the results obtained was published in 1909 by Hale and Adams. The results of a more detailed study of the photographs obtained at that time are indicated in this communication.

The total number of lines measured upon the negatives is slightly larger than that obtained from eclipse negatives in the same region of the spectrum (λ 4800 to λ 6600). Thus a comparison with Mitchell's recent determinations from plates obtained at the eclipse of 1905 shows a total of 901 lines for the eclipse photographs and 1027 for those taken without an eclipse. The chief interest in such a comparison, however, lies in the difference in the lines observed. The eclipse photographs show as strong bright lines nearly all of the strong dark lines of the solar spectrum. On plates taken without an eclipse many of these lines remain dark, or at most show faint bright fringes on either side. The proportion, however, of faint lines of the solar spectrum represented as bright lines in the flash spectrum is much greater than on the eclipse photographs. It seems very probable that this difference in behavior is due to the difference in the level of the observations. The eclipse plates refer to a high level in the solar atmosphere, and, as St. John has shown, the strong lines of the solar spectrum originate at a higher effective level than do the fainter lines. A comparatively low level for the observations made without an eclipse is also indicated by the great strength of the green carbon fluting, and by the appearance of a large number of double reversals among the bright lines observed.

This phenomenon of double reversal appears to be essentially a universal characteristic of the lines in the flash spectrum. In appearance the reversals resemble closely those of the hydrogen lines and of the *H* and *K* lines of calcium, and like them they are always approximately symmetrical. There seems to be no sufficient reason for concluding that these reversals are not due, as in the laboratory, to the radiation of a dense mass of gas through a cooler outer layer of lower density. On this basis the presence of numerous double reversals in the flash spectrum would indicate the existence of comparatively dense gas at the point under observation, and hence a low level in the solar atmosphere.

The wave-lengths of the bright lines in the spectrum of the flash taken without an eclipse have been determined with reference to those of the dark lines of the limb spectrum which are present on the same photographs. Accordingly it is possible to judge of the existence of any systematic displacement of the bright lines, a result which cannot be obtained from eclipse spectra which contain bright lines alone and no standards of reference. A comparison of the wave-lengths of 512 identified lines gives a value: *bright lines – dark lines at limb = – 0.002* angstrom. The preponderance of the negative sign in the case of the individual elements makes it fairly probable that this small quantity is to be regarded as real. If so, it finds a ready explanation in the slightly higher level of the point under observation in the case of the flash spectrum. At this higher level the cause which produces the displacements of the solar lines at the limb toward the red, which is probably a pressure effect, in part, at least, would act less strongly, and the bright lines would have a position to the violet of the dark lines.

A comparison of these measures with those by Mitchell on his eclipse spectra indicates a marked gain in accuracy for the Mount Wilson results. The average deviation of all of the lines common to the two sets of observations between the limits λ 4800 and λ 5880 is as follows: *Eclipse Results*, 0.030 angstrom; *Mount Wilson Results*, 0.012 angstrom. In this comparison blends and double reversals have been omitted. It appears, accordingly, that the greater linear scale of the Mount Wilson photographs contributes notably to the accuracy of the measurements.

It is well known that the lines of certain of the elements of high atomic weight are extraordinarily prominent in the flash spectrum.

If we compare the intensities of these lines on photographs taken with and without an eclipse with the intensities of lines due to such elements as iron, we find the lines of the heavy elements relatively stronger on the plates taken without an eclipse. The heavier elements, therefore, are at a comparatively low level in the solar atmosphere, a result in harmony with that found from investigations of solar rotation and of radial motion in sun-spots.

The close agreement in wave-length between the bright lines of the flash spectrum and the dark lines of the limb spectrum is difficult of explanation on the basis of anomalous refraction in the solar atmosphere. If hypothetical irregular density gradients are used to account for the displacements of the dark lines at the sun's limb as has been done by Julius, it would seem necessary to conclude that they would have a marked effect upon the wave-lengths of the bright lines in the flash spectrum for which the path of the light is very similar. No such effect is found. Neither the regular density gradient nor the presence of irregular density gradients appears to be capable of explaining simultaneously the displacements at the sun's limb and the close correspondence in wave-length of bright and dark lines without the introduction of additional assumptions. The symmetry of the double reversals of the flash spectrum lines is also opposed in general to a theory which ascribes their origin to anomalous refraction and dispersion in the solar atmosphere.

Some peculiar characteristics of the dark line spectrum of the sun's limb are seen on the photographs of the flash spectrum. In some regions, especially near λ 5050, the intensities of the solar lines are so greatly modified as to render identifications difficult. A number of lines of considerable intensity make their appearance, which are not seen at all in the solar spectrum, and conversely, strong lines in the solar spectrum are weakened very greatly at the sun's limb. The identification of the elements to which these lines belong should prove to be a matter of decided interest.

The full details of this investigation with tables showing the results for 1027 bright lines will appear as *Contributions from the Mount Wilson Observatory* No. 95, in the current volume of the *Astrophysical Journal.*